UNIVERSITY OF TORONTO
FACULTY OF APPLIED SCIENCE & ENGINEERING

STA286 Final Report

Does listening to classical music while performing basic calculations help performance?

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Abstract

This paper seeks to investigate whether listening to classical music while performing basic calculations is beneficial to the time and/or accuracy with which the calculations are completed. It also looks at whether or not musical preference plays a role in the effect of music on the participant.

Introduction

The study of how music affects the human mind is an important one in applied psychology. Music is often played in the background when people work, shop or eat out. Furthermore, many students listen to music whilst they study, which often raises the question of whether music helps or hinders concentration and work accuracy. This is not a new question, and many studies have been performed over the past several decades to determine the effect of music on the working human brain.

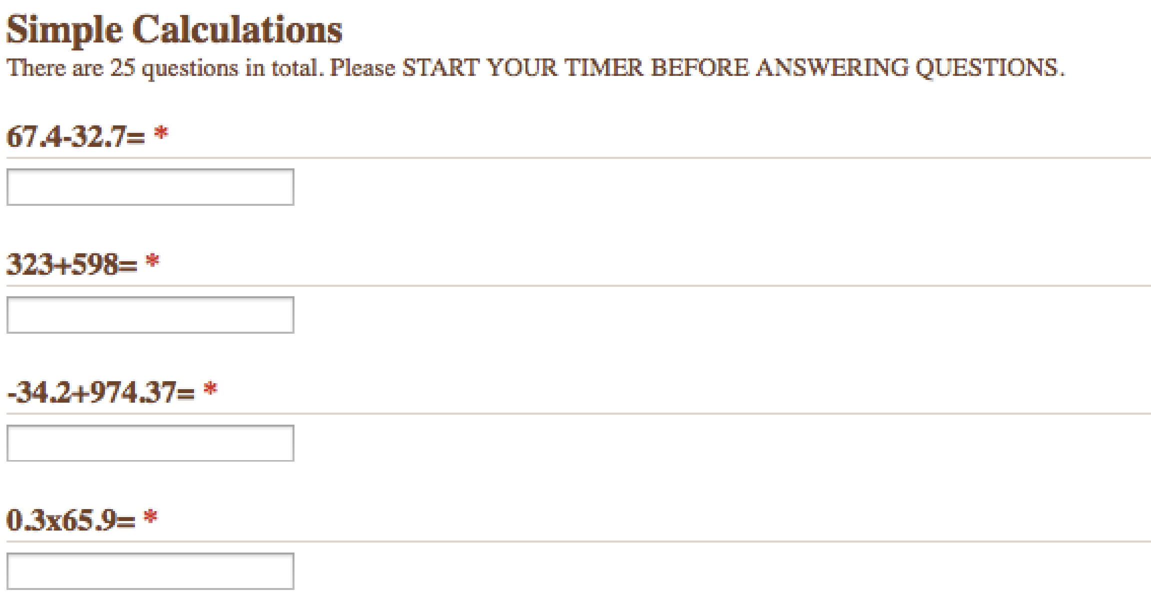
Background

A study from 1977 concluded that stimulative music increased worry and decreased concentration on tests given to subjects compared to when they listened to sedative music. It was noted that the test performance was also affected, but in a complex fashion [1].

A 1997 study compared the effects of pop music on introverts and extraverts during both a memory and a reading comprehension test. A detrimental effect during the memory test was noted in both groups who had listened to music, with the introverts performing worse than the extraverts. The introverts who had listened to music during the reading comprehension test also performed more poorly than either the extraverts or those who had read in silence [2].

Finally, a 2009 study showed that people who listened to music prior to taking an attention test showed higher attentiveness than those who did not listen to music. Those who listened to music while taking the test showed extreme variation in scoring, and no conclusion could be drawn [3].

In our experiment, our participants worked either in silence or while listening to Beethoven's Symphony No. 6 in F Major (The Pastoral Symphony) After filling in some information about themselves, participants were asked to answer several basic mathematics questions and some logic based problems, without the help of paper or a calculator. The questionnaire was made available to participants as a Google Doc form, a screenshot of which is included as **Figure 1** and the entirety of which can be seen in **Appendix A**.



Simple Calculations

There are 25 questions in total. Please START YOUR TIMER BEFORE ANSWERING QUESTIONS.

67.4-32.7= *

323+598= *

-34.2+974.37= *

0.3x65.9= *

Figure 1: A screenshot of the form used by participants in our experiment.

Each participant was asked to time how long it took them to complete the questions, and enter the time at the end of each section.

Experimental Method

In this experiment, two groups of participants were asked to complete an online questionnaire that consisted of twenty-five calculations involving decimal addition, subtraction, multiplication and division; one group answered the questions whilst listening to classical music and the other without. In order to maximize the reliability of data to be acquired, the participants were not permitted to use any calculators or writing utensils. This forced participants to solve the problems relying on only their mental ability and emphasized the purpose of the experiment, which was to examine the correlation between mental behavior and the presence of music. The participants were given as much time as they needed to complete the questionnaire and the time of completion was recorded at the end. Both the correctness of the responses and how quickly the participant reached the end of the questionnaire were observed. Each correct answer was given four marks, for a total of 100 possible marks. Additionally, the online questionnaire also asked each participant to provide basic information about themselves, such as their gender, area and year of study and personal preference for noise levels while studying.

Specific music was selected as a control variable and given to the participants. The chosen collection of classical music was Beethoven's Symphony No. 6 in F Major (The Pastoral Symphony). Participants were exposed to the exact same music with a volume that was adjusted to be the comfortable to them. This made the survey more enjoyable for the participants and allowed us to replicate the common practice of students studying with headphones adjusted to each individual's personal preference.

This experiment was conducted mostly on engineering students at the University of Toronto. This choice of target participants was carried out intentionally to generate more consistent data set for more accurate and reliable results. Despite the relatively narrow range of participant selection, conducting this experiment on engineering students guarantees similar educational backgrounds and problem processing frameworks between the participants, which minimize the number of uncontrolled variables that may have otherwise had a negative impact on data analysis and the final results.

The individual responses and times were separated into two separate categories (with music scores/time and without music scores/time) for data analysis. These groups were then compared on the basis of quality and speed of participants' responses in the different environments using the T-test. In addition to investigating the relationship between music and mental behavior, the experiment also sought to determine what influence each participant's music preference had on their performance. So, those who performed the test whilst listening to classical music were divided into another two groups, representing those who enjoy listening to classical music and those who do not. The performance of each of these sub-groups was then analyzed.

Results and Analyses

Estimation

Using the data collected from University of Toronto Engineering and Arts and Science students, histograms were first populated to give a sense of the data. These histograms can be seen in **Figure 2**.

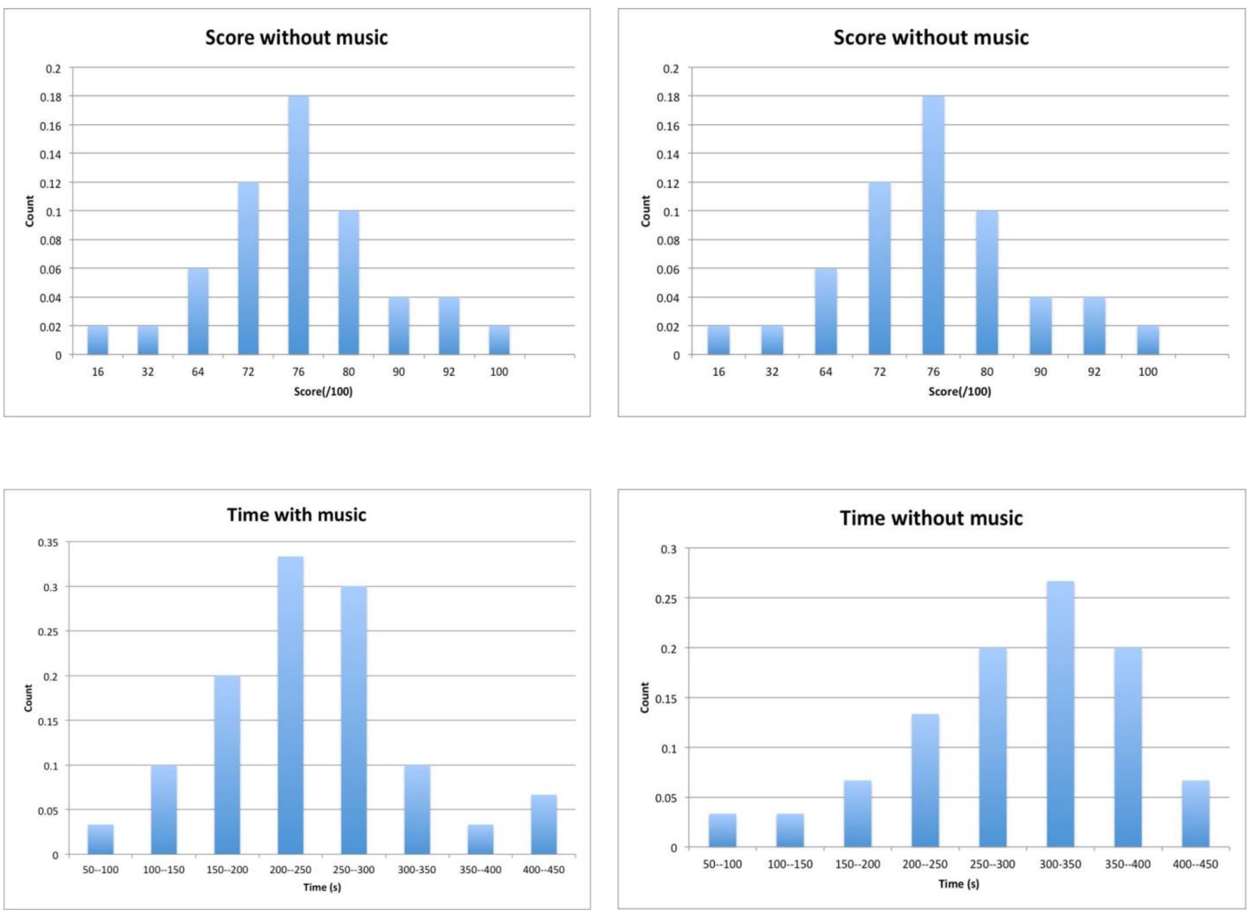


Figure 2: Histograms of raw data.

Confidence Interval Calculation

If x and s are the mean and standard derivation of a random sample from a normal population with unknown variance σ^2, a 100(1-α)% confidence interval for μ is:

$$\bar{x} - t_{\alpha/2}\frac{s}{\sqrt{n}} < \mu < \bar{x} + t_{\alpha/2}\frac{s}{\sqrt{n}}$$

where $t_{\alpha/2}$ is the t-value with degrees of freedom v = n-1, leaving an area of α/2 to the right.

If s^2 is the variance of a random sample of size n from a normal population, a 100(1-α)% confidence interval for σ^2 is

$$\frac{(n-1)s^2}{\chi^2_{\alpha/2}} < \sigma^2 < \frac{(n-1)s^2}{\chi^2_{1-\alpha/2}}$$

where $\chi_{\alpha/2}{}^2$ and $\chi_{1-\alpha/2}{}^2$ are χ^2-values with degrees of freedom v = n-1.

In this case, the sample size is always 30, which means n = 30, and v = 29 degrees of freedom. Using 95% confidence, this gives α = 5% = 0.05 and (1-α)/2 = 0.975.

Using the formulae above, sample means and variances and t-distribution and chi-squared distribution numbers, the confidence interval for sample means and variances with 95% confidence can be calculated. These calculations are summarized in **Table 1**.

Table 1: Means and variances for scores and times with/without classical music

	Mean, X	95% Confidence Interval on X	Median	Standard Deviation S	95% Confidence Interval on S
Calculations with classical music (score) [out of 100 marks]	80.4	[75.25 , 85.54]	82	13.79	[1.62 , 4.63]

Calculations without classical music (score) [out of 100 marks]	68.92	[61.40 ,76.43]	72	20.13	[2.37 , 6.75]
Calculations with classical music (time) [second]	244.21	[209.1 , 279.30]	235.7	94.00	[11.07 , 31.55]
Calculations without classical music (time) [second]	291.98	[260.59 , 323.37]	304.5	84.07	[9.9 , 28.2]

As can be seen in **Table 1**, there is 95% confidence that the mean of the scores of participants who listened to classical music while performing the test falls between 75 to 85. The confidence interval for the mean of participants who did not listen to music was 61 to 76. This suggests that listening to classical music while working is better than silence.

Similarly, the average time it took for participants who listened to music to complete the questionnaire fell somewhere between 209 and 279 seconds. Those who did not listen to music had a mean that fell between 261 and 323 seconds. This suggests that those who listened to music while they worked not only performed more accurately, but completed the task more quickly as well.

Test of Hypotheses

Three separate analyses were performed on the data collected. They were:

Analysis 1: The influence of classical music on calculation accuracy.
Analysis 2: The influence of classical music on calculation speed.
Analysis 3: The influence of classical music preference on accuracy and efficiency.

Analysis 1: The Influence of Classical Music on Calculation Accuracy

Regarding the first analysis, it can be assumed that calculations accuracy by participants with or without music are similar. This gives $\mu 1 = \mu 2$, where $\mu 1$ indicates the mean calculations score of participants who listened to music and μ2 indicates the mean calculations score of those who did not listen to music.

Thus, the null hypothesis is H_0: $\mu_1=\mu_2 \rightarrow (\mu_1-\mu_2=0)$ and the alternative hypothesis is H_1: $\mu_1>\mu_2 \rightarrow (\mu_1-\mu_2>0)$.

The population distribution is assumed to be normal (see **Appendix C** for the confirmation of this assumption). Then, since the population variance is unknown and the sample variance is known, the test statistic is:

$$T' = \frac{(\bar{x}_1 - \bar{x}_2) - d_0}{\sqrt{s_1^2 / n_1 + s_2^2 / n_2}}$$

which has an approximate t-distribution with approximate degrees of freedom:

$$v = \frac{(s_1^2 / n_1 + s_2^2 / n_2)^2}{[(s_1^2 / n_1)^2 / (n_1 - 1)] + [(s_2^2 / n_2)^2 / (n_2 - 1)]}.$$

Suppose the test significance level is chosen to be 5%, meaning α = 5%. Then the critical region for this test would be $t>t_\alpha$, as it is a one-tailed test.

Using this method to analyze the data, it can be calculated that[1]:

$x_1 = 80.4$ and $x_2 = 68.92$ (out of 100 marks)
$s_1 = 13.79$ and $s_2 = 20.13$ and
$n_1 = n_2 = 30$, $d_0 = 0$

It can also be calculated that the degree of freedom is v = 51.3. However, as no data is available for v = 50, this is rounded down to v = 40. The one-tailed test critical region limits bound for v = 40 would be $t_\alpha = t_{0.05} = 1.684$. Hence, the critical region for this case is $t > t_{0.05} = 1.684$.

The value of the test statistic t' = 4.6 >> 1.684, so the null hypothesis can be rejected. Thus, $\mu_1 = \mu_2$ does not hold, which indicates that there indeed exists a significant

[1] All calculation results are presented in **Appendix B**.

difference between scores achieved by participants who listened to classical music while completing the given calculations and those who did not.

Alternatively, using the P-test, P = P (t' > 4.6) is far less than 0.0005. Since standard statistics tables do not provide this information, the actual value for this test cannot be calculated. This also supports the rejection of the null hypothesis.

Analysis 2: The Influence of Classical Music on Calculation Speed

The method from **Analysis 1** can be applied to the data pertaining to calculation speed.

Supposing that times taken by participants to complete the calculations are similar gives $\mu_1 = \mu_2$, where μ_1 indicates the mean calculations time of participants who listened to music and μ2 indicates the mean calculations time of those who did not listen to music.

Thus, the null hypothesis is H_0: $\mu_1=\mu_2 \rightarrow (\mu_1-\mu_2=0)$ and the alternative hypothesis is H_1: $\mu_1>\mu_2 \rightarrow (\mu_1-\mu_2>0)$.

Since using less time is more efficient, it is supposed that working with music is more efficient than working without.

In this case, the calculations are:

$x_1 = 244.21$ and $x_2 = 291.98$ (in seconds)
$s_1 = 94$ and $s_2 = 84.7$ and
$n_1 = n_2 = 30$, $d_0 = 0$

It can be calculated that the degree of freedom is v = 57.3, which is rounded down to v = 40 as before. The one-tailed test critical region limits bound is then $t_\alpha = t_{0.05} = 1.684$. Hence, the critical region for this case is $t < -t_{0.05} = -1.684$.

The value of test statistic t' = -1.19 < -1.684, so it can be concluded that classical music has a positive impact on calculation efficiency.

Analysis 3: The influence of classical music preference on accuracy and efficiency.

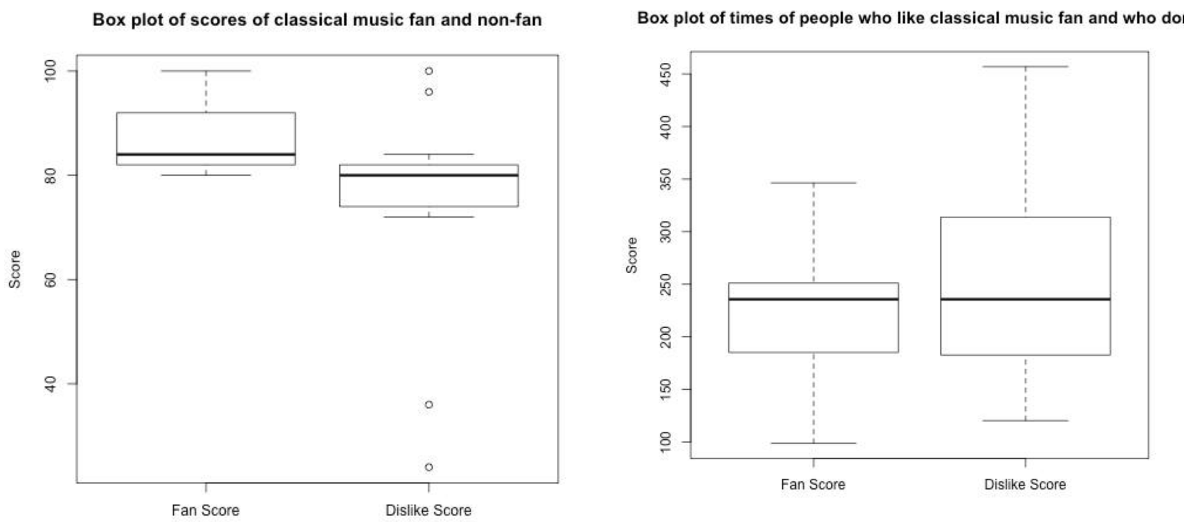


Figure 3: Boxplot of scores and times between classical musical fans and the others.

Whether the participants are keen on classical music was also investigated in the online survey. In the trials that people finished calculations with classical music, there were 11 people who said they liked classical music. The scores and times from these classical music fans were separated from the rest, and results are shown in **Table 2**.

Table 2: Means and variances of scores and times between musical fans and others.

	sample size	**sample mean (score)**	**standard derivation**	**sample mean (time)**	**standard derivation**
classical music fan	11	86.6	3.38	213.34	13.44
the others	19	76.8	4.29	262.08	18.20

The method used here is the same as used in the previous two analyses, also with a 5% significance level.

Degrees of freedom is around 25, so for one-tailed test the t-distribution value is $t_{0.05,25} = 1.708$.

It is obvious that the test statistic value T' is 6.9 far greater than 1.708 or that -8.37 is far less than -1.708. It is highly suggested that the differences of scores and time between classical music fans and the rest are significant.

Correlation between Time and Accuracy

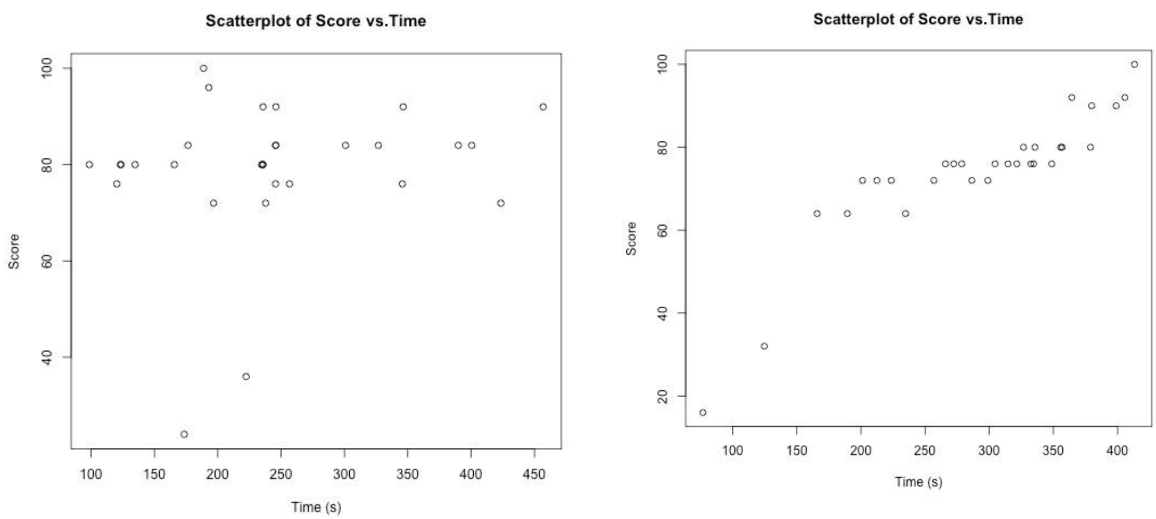


Figure 4: Scatter plots for times versus scores for calculations done with or without music.

The correlation factor can be calculated as

$$r = b_1\sqrt{\frac{S_{xx}}{S_{yy}}} = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}}$$ where $$S_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2$$ and $$S_{yy} = \sum_{i=1}^{n}(y_i - \bar{y})^2$$ and

$$S_{xy} = \sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})$$.

The value of r is between -1 and +1. When r > 0, there is a positive correlation between X and Y, while r<0 indicates negative correlation.

If r is approaching 0, the sample points show little linear relationship, and the regression line is tend to be horizontal, which means knowledge of X is useless in predicting Y.

Moreover, if r approaches +1, the relationship is called linear association.

In our case, the correlation factor between time and accuracy among people who works with classical music is 0.0014. It suggests no regression relationship. However, the correlation factor for those people without music is 0.896, which is close to linear association.

Conclusion

From these results, it can be concluded that listening to classical music while performing calculations has a positive impact on the speed and accuracy with which the calculations are completed. This effect exists independent of whether or not the participant is particularly fond of classical music or not.

Appendix A: The Online Questionnaire

STA286 Project

Congratulations! :D You are participating our STA286 project as part of second year engineering science curriculum.

If you are doing this survey online, please first open one of the following links:
(classical music) https://www.youtube.com/watch?v=v50XkRrp5x8,

Then proceed to the questions with the background music on at your most comfortable volume (or simply without music). You have as much time as you want to answer the following questions, don't use any calculators or writing anything down (do it in your head!)

Thank you for your time.

* Required

General Information

Gender *

- (•) Female
- ( ) Male

Program

Year of Study

Type of Music Chosen *

- (•) Classical
- ( ) Without Music

Are you classical music fan?

- (•) yes
- ( ) no

Simple Calculations

There are 25 questions in total. Please START YOUR TIMER BEFORE ANSWERING QUESTIONS.

67.4-32.7= *

323+598= *

-34.2+974.37= *

0.3x65.9= *

65.1+76.3= *

28x7= *

2672/167= *

323.2*3 *

45+381 *

7326+4273 *

123-658 *

415.7-19.5

67*7 *

19-222 *

89*12 *

6.98-17.46 *

674.7-453.9 *

39.2*4 *

324+409 *

34.4*8 *

1231.5+8412.9 *

Appendix B: Calculations

Table1: Confidence Interval for sample Mean.

Mean	Standard Derivation	Sample size	t-distribution value	Variation of statistic	lower bound	upper bound
80.4	13.79	30	2.045	5.14869245635077	75.2513075436492	85.5486924563508
68.92	20.13	30	2.045	7.51582154795801	61.404178452042	76.435821547958
244.21	94	30	2.045	35.0962357430727	209.113764256927	279.306235743073
291.98	84.07	30	2.045	31.3887291374481	260.591270862552	323.368729137448

Table 2: Confidence Interval for sample Variance.

Variance	Sample size	X-distribution (α/2)	X-distribution (1-α/2)	lower bound	upper bound
13.79	30	45.722	16.047	1.62419453852379	4.62774491745403
20.13	30	45.722	16.047	2.37092357218883	6.75536658363666
94	30	45.722	16.047	11.0713768398286	31.5451792777867
84.07	30	45.722	16.047	9.90181543536586	28.2128002328035

Table 3: T-value and degree of freedom.

x1	x2	s1	s2	N	degree of freedom	T-value
80.4	68.92	13.79	20.13	30	51.3062357467541	4.6
244.21	291.98	94	84.07	30	57.2917731558562	-1.19

Table 4: Calculations for T-test

x1	x2	s1	s2	n1	n2	degree of freedom	T-value
86.60	76.8105263157895	3.38	4.29	11	19	25.1822674553007	6.90974468309149
213.34	262.082105263158	13.44	18.20	11	19	26.1375708924051	-8.37709390167283

Appendix C: Normal Assumption Verification

All estimations and tests of the hypotheses are based on the assumption that the collected sample is normally distributed. Hence, verification that this is indeed the case is required. If the quantile-quantile plot of a population can be fitted into a linear line, it is suggested that the distribution of the population has or at least can be approximated to a normal distribution. From **Figure 2**, it is evident that the data does fit a normal distribution; thus, applying T-distribution test is an adequate analysis technique.

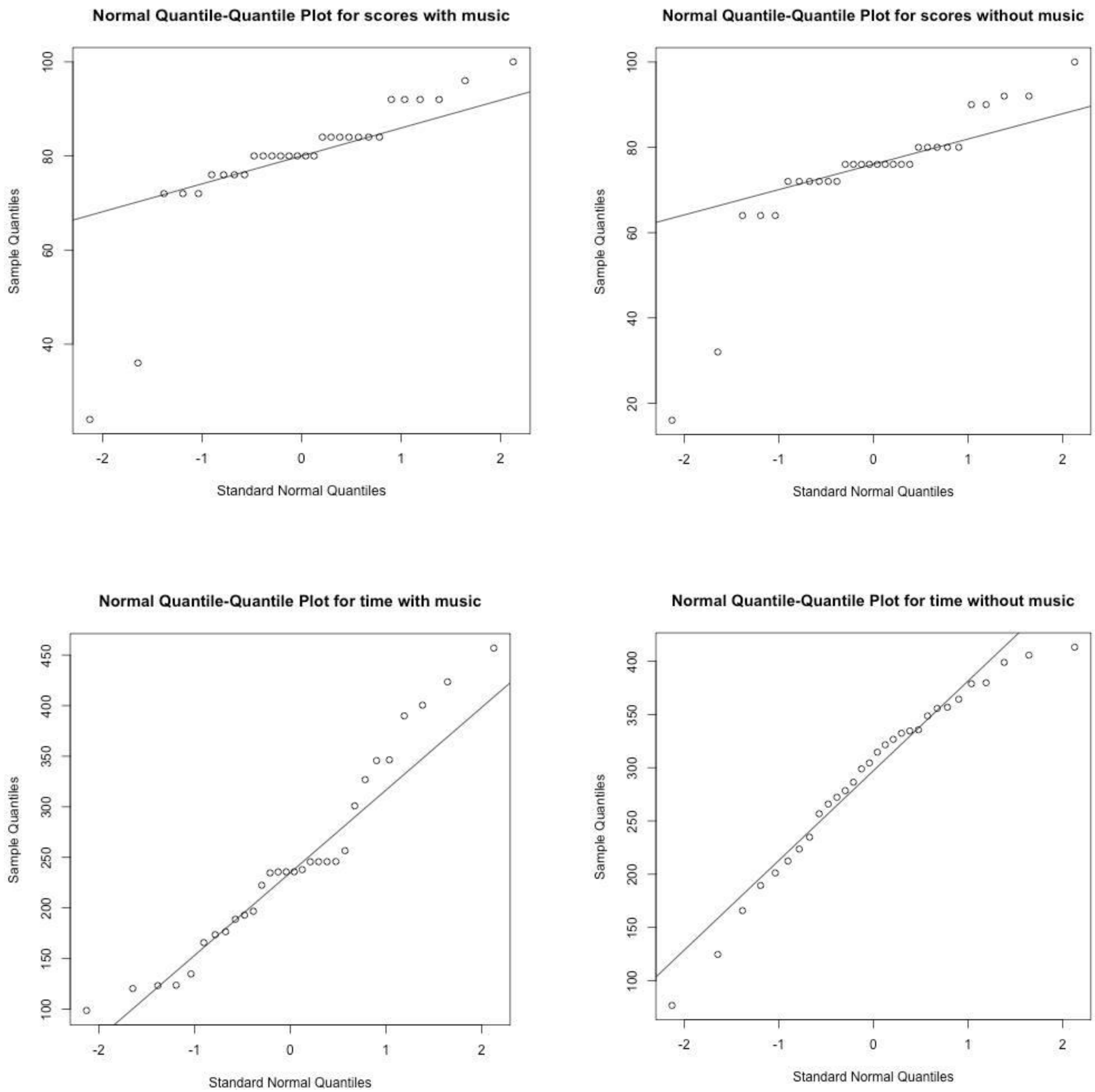


Figure 2: Quantile-Quantile plots

Appendix D: R Code

```
sink("sta286.txt", split=TRUE, append=FALSE)

all.data <- read.csv(file = "tiantian.csv", header=TRUE, sep=",")
withmusic.score <- all.data[["withmusic.score" ]]
withmusic.time <- all.data[["withmusic.time"]]
withoutmusic.score <- all.data[["withoutmusic.score" ]]
withoutmusic.time <- all.data[["withoutmusic.time" ]]
prefer.score <- all.data[["prefer.score" ]]
notprefer.score <- all.data[["notprefer.score" ]]
prefer.time <- all.data[["prefer.time" ]]
notprefer.time <- all.data[["notprefer.time" ]]

# Stats of scores with music
print("withmusic.score:")
withmusic.score.mean = mean(withmusic.score)
withmusic.score.median = median(withmusic.score)
withmusic.score.variance = var(withmusic.score)
withmusic.score.sd = sd(withmusic.score)
print(sprintf("mean = %f", withmusic.score.mean))
print(sprintf("median = %f", withmusic.score.median))
print(sprintf("variance = %f", withmusic.score.variance))
print(sprintf("standard deviation = %f", withmusic.score.sd))

# Stats of scores without music
print("withoutmusic.score:")
withoutmusic.score.mean = mean(withoutmusic.score)
withoutmusic.score.median = median(withoutmusic.score)
withoutmusic.score.variance = var(withoutmusic.score)
withoutmusic.score.sd = sd(withoutmusic.score)
print(sprintf("mean = %f", withoutmusic.score.mean))
print(sprintf("median = %f", withoutmusic.score.median))
print(sprintf("variance = %f", withoutmusic.score.variance))
print(sprintf("standard deviation = %f", withoutmusic.score.sd))

# Stats of times with music
print("withmusic.time:")
withmusic.time.mean = mean(withmusic.time)
withmusic.time.median = median(withmusic.time)
withmusic.time.variance = var(withmusic.time)
withmusic.time.sd = sd(withmusic.time)
print(sprintf("mean = %f", withmusic.time.mean))
```

```
print(sprintf("median = %f", withmusic.time.median))
print(sprintf("variance = %f", withmusic.time.variance))
print(sprintf("standard deviation = %f", withmusic.time.sd))

# Stats of scores without music
print("withoutmusic.time:")
withoutmusic.time.mean = mean(withoutmusic.time)
withoutmusic.time.median = median(withoutmusic.time)
withoutmusic.time.variance = var(withoutmusic.time)
withoutmusic.time.sd = sd(withoutmusic.time)
print(sprintf("mean = %f", withoutmusic.time.mean))
print(sprintf("median = %f", withoutmusic.time.median))
print(sprintf("variance = %f", withoutmusic.time.variance))
print(sprintf("standard deviation = %f", withoutmusic.time.sd))

#/////////////////////////////////////////////////////////////

# Create Quantile-Quantile plot with music score
png(filename = "normal_with_music_score_qq.png", width = 480, height = 480, units =
 "px",
pointsize = 12, bg = "white")
qqnorm(withmusic.score,
xlab="Standard Normal Quantiles", ylab="Sample Quantiles",
main="Normal Quantile-Quantile Plot for scores with music")
qqline(withmusic.score)
dev.off()

# Create Quantile-Quantile plot with music time
png(filename = "normal_with_music_time_qq.png", width = 480, height = 480, units =
 "px",
pointsize = 12, bg = "white")
qqnorm(withmusic.time,
xlab="Standard Normal Quantiles", ylab="Sample Quantiles",
main="Normal Quantile-Quantile Plot for time with music")
qqline(withmusic.time)
dev.off()

# Create Quantile-Quantile plot without music score
png(filename = "normal_without_music_score_qq.png", width = 480, height = 480, units =
 "px",
pointsize = 12, bg = "white")
qqnorm(withoutmusic.score,
```

```
xlab="Standard Normal Quantiles", ylab="Sample Quantiles",
main="Normal Quantile-Quantile Plot for scores without music")
qqline(withoutmusic.score)
dev.off()

# Create Quantile-Quantile plot without music time
png(filename = "normal_without_music_time_qq.png", width = 480, height = 480, units =
 "px",
pointsize = 12, bg = "white")
qqnorm(withoutmusic.time,
xlab="Standard Normal Quantiles", ylab="Sample Quantiles",
main="Normal Quantile-Quantile Plot for time without music")
qqline(withoutmusic.time)
dev.off()

#////////////////////////////////////////////////
# Create scatterplot studies the relationship between the time and score generated in
 presence of music
png(filename = "withmusic_score_vs_time.png", width = 520, height = 480, units = "px",
pointsize = 12, bg = "white")
plot(withmusic.time,withmusic.score, xlab="Time (s)", ylab="Score",
main="Scatterplot of Score vs.Time")
dev.off()

# Create scatterplot studies the relationship between the time and score generated in
 abscence of music
png(filename = "withoutmusic_score_vs_time.png", width = 520, height = 480, units =
 "px",
pointsize = 12, bg = "white")
plot(withoutmusic.time,withoutmusic.score, xlab="Time (s)", ylab="Score",
main="Scatterplot of Score vs.Time")
dev.off()

#////////////////////////////////////////////////
# Create box plot for comparing results from participants who love classical music and
 those who dont
png(filename = "score_box_plot.png", width = 480, height = 480, units = "px",
pointsize = 12, bg = "white")
boxplot(prefer.score, notprefer.score, names = c("Fan Score", "Dislike Score"),
ylab="Score", main="Box plot of scores of people who like classical music fan and who
 don't")
dev.off()
```

```
# Create box plot for comparing results from participants who love classical music and
 those who dont
png(filename = "time_box_plot.png", width = 480, height = 480, units = "px",
pointsize = 12, bg = "white")
boxplot(prefer.time, notprefer.time, names = c("Fan Score", "Dislike Score"),
ylab="Score", main="Box plot of times of people who like classical music fan and who
 don't")
dev.off()

#End the sinking
sink()
```

Appendix E: Original Data

withmusic.score	withoutmusic.score	withmusic.time	withoutmusic.time	prefer.score	notprefer.score	prefer.time	notprefer.time
24	16	173.5	76.8	84	24	173.5	237.8
36	32	222.4	124.7	84	36	222.4	423.5
72	64	196.7	165.8	84	72	196.7	245.6
72	64	237.8	189.4	80	72	345.7	120.3
72	64	423.5	234.8	80	72	235.7	134.7
76	72	245.6	201.2	92	76	245.72	123.2
76	72	120.3	223.6	92	76	346.4	234.6
76	72	256.6	212.4	84	76	98.6	165.7
76	72	345.7	256.8	80	76	245.7	235.6
80	72	134.7	286.4	100	80	123.6	300.89
80	72	123.2	298.9	92	80	256.6	400.5
80	76	98.6	278.5		80		326.8
80	76	234.6	265.9		80		176.5
80	76	165.7	272.3		80		389.9
80	76	235.7	321.5		84		456.9
80	76	235.6	332.4		84		245.9
80	76	123.6	304.5		84		235.7

84	76	300.89	334.6		96		192.9
84	76	245.72	348.7		100		188.8
84	76	400.5	314.6				
84	80	326.8	335.6				
84	80	245.7	326.7				
84	80	176.5	356.8				
84	80	389.9	378.9				
92	80	346.4	355.7				
92	90	456.9	379.8				
92	90	245.9	398.9				
92	92	235.7	364.3				
96	92	192.9	405.7				
100	100	188.8	413.2				